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CLIII.

(Vol. VII. January, 1878.)

ON IGNITING BLASTS BY MEANS OF ELECTRICITY.

By JULIUS H. STRIEDINGER, C. E., Member of the Society.

For which the Norman Book Prize was awarded, November 7th, 1877.

I.

The great blast recently attempted at Port Henry Iron Mine was only a partial success. Its failure has been attributed to either imperfect electrical arrangements or to the freezing of the nitro-glycerine compounds used, or both.

On the other hand we learn, that two serious accidents have happened within a few months at the mouth of the Sutro Tunnel, both through the sudden and apparently unaccountable discharge of a number of exploders. An investigation into the cause of these accidents clearly established the fact, that in the exceedingly dry atmosphere of the high plateau between the Sierra Nevada and the Rocky Mountains, certain frictional fuses can be set off by electricity accumulated in the human body.

Such discouraging occurrences naturally lead us to inquire whether, in our present state of knowledge of high explosives and their mode of

detonation no reliable means exist of preventing a repetition of similar misfires and premature explosions. In considering these points the following questions suggest themselves :

1. *Is it possible to fire, with certainty, simultaneously a large number of mines ?*

2. *Can frozen nitro-glycerine compounds be detonated?*

3. *Can the use of over-sensitive fuses be avoided?*

That a large number of mines can be simultaneously successfully fired was demonstrated by General Newton's blast of Hallet's Point Reef, where over 3,600 separate charges were simultaneously exploded. The method here adopted consisted in dividing all the mines to be ignited by electricity into a large number of independent groups, supplying sufficient battery power for each group to fire with certainty all the fuses in the group, and then at the requisite moment simultaneously closing the circuits of all the groups by means of the gravity circuit closer of J. H. Striedinger and A. Doerflinger, illustrated by the annexed drawings. *Plates I, II and III.*

As the number of cups and pins can be increased at will, and since the probability of firing a number of mines increases with the number of groups into which they are divided, and the probability of detonating a single charge is proportional to the number of independent fuses placed into it, it follows, that the writer's *method of simultaneously firing an unlimitea number of independent groups offers a sure means of preventing misfire,* and that five thousand charges can with the same degree of certainty be ignited as ten.

In reference to the second point, it is only necessary to state, that numerous experiments have proved, that *nitro-glycerine compounds can as surely be detonated when frozen as when not congealed,* provided a fuse, containing not less than twenty grains of good fulminate of mercury * or its equivalent, is used.

Before answering the 3rd question :

" *Can the use of over-sensitive fuses be avoided without giving up blasting by means of electricity,*" we should state, that the frictional blasting machine and frictional electric fuse were successfully used by the Sutro Tunnel Company for a number of years without any accident whatever, until last December, since which time the two serious ones, already mentioned, have occurred.

* Compare Annual Report of the Chief of Engineers U.S.A., 1875. Part 2. Page 209.

The explanation which can be given is, that competing manufacturers have been in the habit of increasing more and more the sensitiveness of their exploders in order to earn for them the reputation of certainty of detonation in great numbers.

The use of over-sensitive exploders may be avoided :

1st. *By the exclusive employment of a safe priming—(as for instance, Brown's composition No. 4)—in the construction of electric fuses.*

2d. *By the examination of fuses before they are given to the blaster.*

By exposing each fuse to electric discharges somewhat exceeding those derived from the accumulated electricity in the human body the safety of the exploder is readily proven. A Holtz machine without Leyden jars, or the induction coil connected with a few constant cells are suitable apparatuses for such tests.

The objections to these two directions are, that their practical application still more reduces the already limited number of exploders, which can be simultaneously fired with the frictional electrical machines as found in our market at present. Hence for the safe detonation of a great number of independent charges, the use of an entirely different electrical apparatus becomes necessary.

Since even our "Standard Fuses," which of all low-tension fuses seem to be the most susceptible to frictional electricity, have only about one-third of the sensitiveness of very safe frictional fuses, it follows :

3d. *The adoption of low-tension fuses in conjunction with magneto-electric machines or voltaic batteries is the most radical way of preventing the accidents consequent on the risk in handling over-sensitive fuses.*

Again, since in the United States both magneto-electric machines and galvanic batteries have been built, which can simultaneously ignite thousands of our "Standard Fuses," and furthermore, since low-tension fuses admit of quick and accurate testing, less perfect insulation, various grouping, &c., &c., we can but advise a more liberal use of magneto-electric machines or galvanic batteries and low-tension exploders in place of frictional blasting machines and frictional electrical fuses.

In the following pages will be found *descriptions and drawings of the low-tension fuse, the galvanic batteries and battery frames as successfully used at the demolition of Hallet's Point Reef, Hellgate, on September* 24, 1876.

II.

Our Standard Fuse—A Lafflin & Rand Fuse, improved by the Writer.

Whenever a galvanic current passes through a wire it meets a certain fixed resistance, in overcoming which the energy expended is converted into an equivalent amount of heat.

This property possessed by the current is utilized in the low-tension fuses, the priming of which is fired by heating a fine wire stretched across the ends of two copper wires, whose open ends are connected with the poles of the battery.

Professor Abel, F. R. S., stated before the Society of Telegraph Engineers, in a paper relating to electrical fuses :*

"The highly permanent character of the platinum, combined with the comparatively great resistance which it opposes to the passage of an electric current, has led to its being almost exclusively used until quite recently as the material for the construction of the bridge in low-tension fuses."

And again :

"Both the German silver and platinum-silver alloy are greatly superior to platinum in regard to the resistance opposed to the passage of a current, and the heat consequently developed in given lengths of wire of a particular diameter. Comparative experiments made by me (Prof. Abel) appear to warrant the conclusion that a wire consisting of the alloy composed of about 66 parts of silver and 33 of platinum is not only superior to a platinum wire of considerably smaller diameter, as regards the resistance it offers to the passage of an electric current; but that it is also, practically, quite equal in this respect to a German silver wire of the same diameter, and is, at the same time, greatly superior to the latter in its power to resist corrosion."

Based upon the assertions of so high an authority as Professor Abel, silver-platinum wire of 0.0014 inch diameter was at once imported from England.

Our subsequent experiments with said wire proved its superiority over the materials until then used in the construction of electric fuses on this side of the Atlantic.

The most judicious length of the silver-platinum wire bridge and the selection of the fuse priming remain yet to be discussed.

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* Compare : Journal of the Society of Telegraph Engineers, Vol. III., No. 8, 1874. Notes relating to electric fuses, by Professor Abel, F. R. S., Member of Council.

Since the sensitiveness of exploders increases with the diminution of the value of fc^2, the product of resistance of the fuse at the moment of explosion, and the square of the needful current,* with a view of selecting the most sensitive low-tension fuse, the constants f and c of a variety of fuses were experimentally found ; platinum-silver wire forming chiefly the material for the bridges, while fulminate of mercury and gun-cotton were alternately employed as priming agents in the fuses.

Although Professor Abel's directions for making gun-cotton priming (compare notes relating to electric fuses, Journal, Society Telegraph Engineers) for very fine wire bridges were strictly adhered to, both in the preparation and application of the "gun-cotton dust—fulminate of mercury mixture"—yet the technical difficulty of maintaining the pulverized gun-cotton in close contact with the thin platinum-silver wire seems not to be entirely overcome by this improvement over the usual method of pressing a small tuft of gun-cotton wool around the wire bridge, since a shaking of the "gun-cotton dust" fuses facilitated their explosion when they were exposed to the heating action of a galvanic current.

The well known French chemist, Champion, recommends for securing a permanent contact between the wire bridge and the gun-cotton priming, the application of the latter in the form of collodium. This we tried also, but found that fuses prepared in this manner required a stronger current than common gun-cotton fuses, unless especial care is taken in drying them.

Fulminate of mercury, although it explodes at a lower temperature than gun-cotton (we found the exploding temperature of the former to be 368° Fahrenheit, and of the latter 432° Fahrenheit†), yet requires being a better conductor of heat than gun-cotton, a little intenser current than pyroxilin for inflammation, when used as priming agent for low-tension fuses. On the other hand, fulminate of mercury is less hygroscopic than gun-cotton, and, owing to its greater specific gravity, packs itself better around the fine wire bridge—properties which assure the greater uniformity in the time of explosion of fuses, when exposed to the action of equal currents.

These considerations resulted in the exclusive use of fulminate of mercury as priming for our standard fuses.

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* Compare : Transactions of the Am. Soc. C. E., Vol. VI., page 186.

† Champion gives as the exploding temperature of Gun-cotton, 428° Fahrenheit ; and of Fulminate of Mercury, 392° Fahrenheit. (Compare : La dynamite et la nitroglycérine par P. Champion, Paris, 1872, page 30.)

The comparison of the sensitiveness of the different fulminate of mercury fuses led us to the adoption of a platinum-silver bridge of 0.0014 *inch diameter, and* $\frac{4}{16}$ *inch in length,* which decision is in entire accordance with the determinations of General Henry L. Abbot, U. S. E., who by his method devised for use at the School of Submarine Mining, at Willet's Point, has determined the constants of many different types of fuses, of which the following tables exhibit the data for four superior exploders.*

DESCRIPTION OF SAID FOUR FUSES.

Type.	Fine wire bridge consists of	Primed with
A..................	3-16'' platinum wire.........0.025 inch in diam.	Fulminate of mercury.
B............... .	3-16'' platinum-silver wire..0.0014 "	" "
C..................	3-16'' gold-iron wire........0.0020 "	" "
Our Standard fuse	4-16'' platinum-silver wire..0.0014 "	" "

CONSTANTS OF SINGLE FUSES.

Type.	Resistance in Ohms.			Current in Webers to effect explosion.
	Cold.	At explosion.	Diff.	
A........................	0.72	0.82	0.10	0.45
B........................	1.49	1.57	0.08	0.33
C........................	1.87	1.96	0.09	0.34
Our Standard Fuse........	1.90	2.01	0.11	0.28

TRIALS WITH FUSES COUPLED IN SERIES.

Type A.		Our Standard Fuse.	
Currents varying from	Per cent. fail.	Currents varying from	Per cent. fail.
1.0 to 1.2 Webers.	33	0.40 to 0.45 Webers.	67
1.2 to 1.3 "	8	0.45 to 0.50 "	44
1.3 to 1.4 "	3	0.50 to 0.55 "	33
1.4 to 1.5 "	1	0.55 to 0.60 "	17
1.5 and more.	0	0.60 to 0.65 "	8
		0.67 and more.	0

* Compare: General Abbot's paper, "Theory of Simultaneous Ignitions," No. XXXIX, printed papers, pages 147 and 148.

Since the sensitiveness of a fuse is measured by the smallness of the value of its fc^2, the resistance of the fuse at the moment of explosion (f), multiplied by the square of the needful current (c), we now have a ready means of comparing the merits of the above four low-tension fuses.

Adopting this mode, we find :

Type of Fuse.	f = resistance of each fuse at the instant of explosion.	c = current in Webers needful to fire		fc^2 =
		Single Fuses.	Fuses united in series.	
A...........................	0.82	0.45	.	0.16605
B..............................	1.57	0.33	.	0.170973
C,............................	1.96	0.34	.	0.226576
Our Standard Fuse............	2.01	0.28	.	0.157584
A..............................	0.82	.	1.5	1.845
Our Standard Fuse..............	2.01	.	0.67	0.902289

Which means that *our Standard fuse is the most sensitive in the list of these four exploders*, which actually are the best kind of fuses at present employed in this country.

Since our fuses were to be used for submarine blasting, and likely to be exposed during three days to a considerable pressure, *experiments for the purpose of employing an impermeable fuse covering were instituted and determined after the following results were arrived at :*

1. *Nitro-glycerine is less permeating than sea-water.* Fuses, which get spoiled in water after one day's submersion, will be still serviceable after three days' exposure to nitro-glycerine.

2. *Laflin & Rand's copper shell fuses, covered at least* $\frac{1}{8}$ *inch with good gutta percha, and, previous to their employment, additionally protected with a thin* ($\frac{1}{40}$ inch thick) *coating of paraffine, will, when kept in a depth of* 40 *feet, resist the permeation of salt water, at least, four days.*

Description of our low-tension Standard Fuse. *Plate IV.*

In the construction of this exploder, three copper cylinders are used, of which the smaller ones, being open both on top and bottom, are employed for confining the priming agent – ten grains of fulminate of mer-

cury—while the larger one of the three copper cylinders is closed at the base, and when provided with the strengthening charge—ten grains of fulminate of mercury—is slipped on the copper priming case. The connecting wires pass through the larger one of the open copper cylinders; they project beyond its top nearly one-quarter of an inch, and when one-quarter of an inch apart, are secured in their position by molten sulphur. The fine bridge is soldered on the terminals, which are then squeezed together a little in order to relieve the strain on the bridge. The other of the open and short copper cylinders is pressed into the wire cup until it rests upon the sulphur filling, when it is charged with the priming and sealed by a rubber wad. The priming case being now finished, the copper cap containing the additional ten grains of fulminate of mercury is pushed on it and the whole covered with at least one-eighth inch of good gutta-percha.

For the use at the final blast at Hallet's Point, Hell Gate, our standard fuses were made up in bunches forming continuous and perfectly insulated circuits of twenty-one exploders each. The distances between the fuses while being the same for each set of twenty-one, varied from twenty to twenty-five, thirty and thirty-five feet.

The fine platinum-silver wire and the gutta-percha covered connecting wire, the latter of size 18 × 9, American gauge, were furnished, after having passed our examination, to the fuse manufacturer, the Laflin & Rand Powder Co.

Dimensions of our Standard Fuses.

Length of wire bridge........................	$\frac{1}{4}$	inch in the clear.
Diameter of platinum-silver bridge wire..................	0.0014	inch.
Length of longer copper cylinder containing wire terminals,	$\frac{7}{8}$	"
Diameter of longer copper cylinder containing wire terminals,	$\frac{3}{8}$	"
Length of shorter copper cylinder closed with rubber wad,	$\frac{13}{32}$	"
Length of copper cap containing the strengthening charge,	$\frac{15}{16}$	"
Total length of fuse before gutta-percha covering is put on,	$1\frac{1}{2}$	"
Diameter of gutta-percha covered fuse..................	$\frac{5}{8}$	"
Size of connecting resp. fuse wires......................	18×9	A. G.
answering to a copper wire of..................	0.040303	inch diam.
covered with one coat of gutta-percha increasing the total thickness of the connecting wire to....	0.11443	inch.

III.

Our galvanic batteries and battery frames. Designed by the writer.

Plates V and VI.

Each of the *twenty-three large plunge batteries* was built up by means of ten-cell batteries consisting of a wooden box containing ten glass cups filled with "bi-chromate solution" and a wooden bar suspending ten zinc-carbon elements. Stout copper straps solidly connected the ten elements for "intensity." The extreme elements of each ten cell battery were provided with binding screws for No. 10 A. G. wire; in addition to which nine 10-cells bars also had screw posts for each element. (This was done as a means of enabling the building up of batteries of any number of cells.) The bar was made of very well seasoned wood. Each cell, as received from the manufacturer, Mr. Chas. T. Chester, when filled with fresh fluid offered in the beginning of immersion not less than 1.98 Volts electro-motive force and a resistance not exceeding 0.12 Ohms.

Dimensions of one 10-cell plunge battery as used in the final blast.

Outside measure of wooden box containing the ten cells,	$7'' \times 7\frac{1}{2}'' \times 17\frac{7}{8}''$
Each glass cup was in the clear........................	$6'' \times 4\frac{5}{8}'' \times 1\frac{1}{4}'$
Each of the plates measured.........................	$4\frac{1}{2}'' \times 6''$
and when lowered into the fluid the elements opposed,	$4\frac{1}{2}'' \times 4\frac{1}{2}''$
Distance in the clear between zinc and carbon plates of one element....................	$\frac{3}{16}''$
Size of copper strap connecting the carbon plate of one cell with the zinc plate of the adjacent cell...........	$3\frac{1}{2}'' \times 2'' \times \frac{1}{24}''$
Size of wooden bar supporting the elements............	$17\frac{7}{8}'' \times 2\frac{5}{8}'' \times \frac{7}{8}''$
but excluding a tenon of..........................	$\frac{7}{8}'' \times \frac{13}{16}'' \times \frac{7}{8}''$
on each end for guiding the bar of the plunge battery.	
Weight of one battery box containing the ten glass cups filled with the "solution".........................	44 pounds.
Weight of cross-bar with its elements and binding post,	14.5 "

Forty-eight of such ten-cell plunge batteries, as described above, *were placed into each of the two large battery frames.*

Each battery frame had two tiers of shelves, which were divided longitudinally into two halves and by means of posts and guide-boards laterally subdivided into six sections, forming altogether $2 \times 2 \times 6 = 24$

partitions, or 24 divisions for two ten-cell batteries. The battery boxes rested directly on the shelves, while the wooden bars carrying the elements were suspended by means of insulated iron bolts from iron bars, which being placed parallel to the centre bracing, extended through the whole frame. As there were laterally four rows of batteries on each of the two shelves, every battery frame was provided with eight iron bars from which the elements were suspended. The bars were supported at their extremities by the front and rear wooden slides, which again could be vertically raised and lowered by means of the simple mechanical device of a rack and pinion motion. The partition boards of the frame were morticed through in order to act both as "leads" for the tenons of the wooden bars and as guides for the iron hoisting bars. Wooden chocks attached to the uprights of the frame held the slides to and allowed them to glide along the narrow faces of the battery frame. In order to facilitate the labor of raising and lowering the slides, four balance weights were employed with each frame. The suspending ropes of the balance weights worked on sheaves in the front and rear cap pieces, and were fastened to the posts of the slides. The whole being nicely equipoised, well proportioned and finished, little exertion sufficed to lower the elements into or to raise them out of the cells by simply giving the crank four-tenths of a turn. Preparatory to the final blast, the elements were hoisted up, the battery boxes were withdrawn from the shelves and filled with the standard measure of the "bi-chromate solution."

Every part having been made perfectly fitting an easy "bringing home" of the boxes was the only requirement in returning them.

When any of the elements needed repairing, the nuts of the suspension rods were unscrewed, the rods removed and the wooden bar holding the elements was taken out of the tenon slide hole by raising the bar a little more on one side. With the same facility the elements were replaced.

Dimensions of each battery frame and its characteristic parts.

Space occupied by frame	$7' \times 6'3\frac{1}{2}'' \times 11'8\frac{1}{2}''$
Interior dimensions of one two 10-cell division in lower tier	$18'' \times 29\frac{1}{2}'' \times 15\frac{1}{4}''$
Do. do. in upper tier	$18'' \times 28\frac{1}{4}'' \times 15\frac{1}{4}''$
Width of slides	$32''$
Size of each slide-post	$3'' \times 5'4\frac{1}{4}'' \times 3''$

Size of each battery frame-post	$3'' \times 5'8'' \times 3''$
" " " battery frame-post brace	$3'' \times 4'10\frac{1}{2}'' \times 2''$
" " " " " cap piece	$5'2\frac{1}{2}'' \times 4\frac{1}{2}'' \times 3''$
Weight of one slide	46 pounds.
Size of each iron hoisting bar	$11' \times 2'' \times \frac{7}{8}''$
Weight of one iron hoisting bar	64.5 pounds.
Size of one suspending rod	$\frac{1}{8}''$ diam. $8\frac{3}{8}''$ long.
Diameter of spherical head of suspending rod	$\frac{5}{16}''$
Size of one cast-iron balance weight	$11'' \times 11'' \times 11''$
Weight " " " " about	326 pounds.

After the final examination and electrical testing of the cells, which gave very satisfactory results, the batteries were united into twenty-three large blasting batteries of which the "Westerly" frame, *Plate I, Fig.* 1, contained seven batteries (Nos. 3, 6, 7, 8, 9, 10 and 11) each of forty-four cells, and four batteries (Nos. 1, 2, 4 and 5) each of forty-three cells, while the four hundred and eighty cells of the "Easterly" frame were coupled in twelve large batteries, each of forty cells. The wire connection between the negative poles of these twenty-three batteries and the twenty-three brass pins of the circuit closer was then undertaken, while the screw cups of the positive poles of the twenty-three large plunge batteries and the stems of the twenty-three mercury cups were each provided with an "8-wire fork."

In order to prevent the fouling of any of the wires directly connecting with the batteries, they were secured by means of ½-inch cotton tape to the hoisting bars of the battery frame, and also supported by lashing from the ceiling of the battery-house wherever possible.

After the drill-holes were primed, the lead-wires run to the battery-house, and the water allowed to enter the rock excavation, the groups were tested once more, labeled and classified. (The observed resistance of single groups—twenty of "Our Standard Fuses," one "lead" and one "return" wire—lay between 37.0 Ohms and 40.7 Ohms at a temperature of the water, of 63° Fahrenheit.) Groups of practically equal resistance were now united in bunches of eight, and finally connected with the "8-wire forks;" care was taken to unite the eight group branches in proportion to their joint resistance with a more or less powerful battery, viz., a 44, 43 or 40 cell battery.

Description of the manufacture of the "Bichromate Solution."—180 pounds of pure bichromate of potassa were dissolved in 150 gallons of

hot water of a temperature of 135° Fahrenheit. When the solution had cooled down to 85° Fahrenheit, 30 gallons of sulphuric acid of 1.83 specific gravity were gradually added to it, while the fluid was agitated. Specific gravity of solution 32.2° Beaumé at 160° Fahrenheit. The color of the "solution" was of a beautiful red, and unlike the mercantile article of "bichromate solution," which is of chestnut color.

The illustrations accompanying this paper are as follows:

Plates I, II and III.

Gravity Circuit Closer of J. H. Striedinger and A. Doerflinger, as used at the demolition of Hallet's Point Reef, Hellgate.

Fig. 1. Elevation of the circuit closer.

a′, position occupied by movable pin plate previous to the lowering of the galvanic elements into the cells. Some of the pins are shown as connected with the wires going to the negative poles of the batteries.

a, position occupied by pin plate just before the touching off of the blast.

b, fixed plate provided with the mercury cups, of which some are shown as united by means of the wire forks, with the groups of fuses.

c, position occupied by intercepting table until the preparations were finished for the final closing of the circuits, when the intercepting table was removed. (Compare Figs. 13 and 14, Plate III.)

Fig. 2. Full top view of gravity circuit closer.

Fig. 3. Elevation of gravity circuit closer, showing position occupied by movable plate after the severing of the suspending cord by the explosion of the small cartridge or torpedo.

The pins are, by means of the mercury filling, in metallic contact with the mercury cups.

Fig. 4. Top view of circuit closer below plane *m n*.

Fig. 5. Elevation of brass pin. *a*, sectional view of part of the movable pin plate.

Fig. 6. Top view of brass pin.

Fig. 7. Elevation of mercury cup. *b*, sectional view of part of fixed plate.

Fig. 8. Top view of mercury cup.

Fig. 9. Section of brass pin.

Fig, 10. Section of mercury cup and its rubber tubing, and rubber washer insulators.

Fig. 11. Bottom view of mercury cup.

Figs. 12 and 13. Side views and top and bottom views of intercepting table, which prevents the accidental closing of the circuits when placed between the pin and mercury cup plates. (Compare Fig. 1, Plate I.)

Plate IV.

Our Standard Fuse as used at the demolition of Hallet's Point Reef.

Figs. 1 and 3. Outside and sectional views of said fuse. Full size.

Fig. 2. Perspective view of the three copper shells employed in the construction of said fuse.

Plates V and VI.

Our Galvanic Batteries and Battery Frames as used in the final blast.

Fig. 1. Side elevation of "Westerly" frame. The 480 zinc carbon elements are united into eleven large blasting batteries.

Fig. 2. Plan of foundation timbers of battery frame.

Fig. 3. Cross section on *a b*. (Compare Fig. 1, Plate V.)

Fig. 4. End elevation of battery frame. The slides are entirely lowered.

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CLIV.

(Vol. VII.—January, 1878.)

A PECULIAR CASE OF FAILURE IN A WATER MAIN.

A Paper by D. McN. STAUFFER, C. E., Member of the Society.

READ DECEMBER 5TH, 1877.

The accompanying sketch (Plate VII.) illustrates what, to the best of my knowledge, is a unique case of failure in a water main, and is sufficiently curious to be noted.

As shown on the drawing, a hole 1 in. × ½ in. was scoured entirely through a cast-iron pipe ⅜ in. thick and four inches inside diameter. Unfortunately the break was repaired and the lead melted out of the "bell" of the adjoining pipe before an observation could be made, so that we can only get at the cause by an examination of the injured portion of the pipe.

The water flowing through this pipe is supplied from a reservoir 5½ miles distant, and at an elevation of 280 feet above the portion in question. The pressure taken at the nearest fire-plug varies from 80 to 100 lbs. per square inch, depending upon the time of observation and the amount of water being drawn off. The soil in which the pipe is laid contains much fine, sharp sand, and it is the presence of this sharp sand, we take it, that accounts for the mischief.

The hole was in the *top* of the pipe, and is evidently the result of a scouring action ; there is no sign whatever of a flaw in the iron, which is of an excellent quality.

The cause was apparently as follows : The lead used in making the joint was, very probably, carelessly poured and as imperfectly caulked, leaving a weak spot in the joint at the "pouring gate," on top of the pipe.

The lead giving way under the pressure, allowed a small jet of water under an average pressure of 90 lbs. per square inch to strike the pipe just outside of the bell. The soil above, mainly sharp sand, continually caving in from the action of the water, furnished an excellent grinding material, and the jet was the active agent, thus forming, in fact, a natural "sand-blast," exactly similar in effect to the machine so usefully applied by Mr. Tilghman. The outside of the pipe was brightly scoured within the limits indicated by the dotted lines on the drawing, and grains of sharp sand were still imbedded in the pits shown in the sketch. Just how the grinding material got *under* the "bell," as it evidently did, is the one thing not easily explained, as there is no evidence of any sand *within* the pipe. Four days before the water burst through the injured pipe, this joint was laid bare in making some repairs, and there was no leak then apparent, so that this ⅜ in. of cast-iron must have been scoured through *within* that time.

DISCUSSION

On a Peculiar Case of Failure in a Water Main.

Mr. George S. Greene, Jr.--I think this not a very uncommon case of failure. Mr. A. W. Craven, when Chief Engineer of the Croton Aqueduct, had in his office specimens of pipe cut by sand and a current of water. The explanation given in the paper by Mr. Stauffer appears fairly to account for the effect produced, although the time, four days, seems somewhat short for cutting through a pipe ⅜in. thick.

Mr. W. H. Paine.—At the caisson for foundation of the Brooklyn Bridge, sand was blown out through a pipe 3½in. diameter (a short piece at the lower end was only 2½in. diameter). At the upper end an elbow was necessary to properly direct the stream of sand. The iron in these

elbows was $\frac{3}{8}$in. thick. Under a pressure of $34\frac{1}{2}$ pounds, the greatest pressure, the stream of sand cut through every kind of iron tried except Franklinite, in one half hour. Franklinite stood longer.

Mr. C. L. McAlpine.—A similar tube was used at the Harlem River Bridge for months, at about the same pressure as that mentioned by Mr. Paine, but with no perceptible wear of the pipe, although a large quantity of sharp sand, gravel and stones was ejected with a force that sent stones through the atmospheric air to a distance of 60 feet.

Mr. Wm. J. McAlpine.—I have closely examined the pipe in question, and with a new, sharp file.* I find the edges of the hole to be a white, chilled iron, and other parts of the pipe of materials of various grades, from very soft to very hard iron. In some places I have picked out some of the material with the point of a pocket knife. The pipe was undoubtedly a defective one, and at the place in it where the leak occurred, scoria or other imperfect material with no more consistency than coke, overlaid the very thin sheet of hard iron. The latter was evidently *too weak* to withstand the internal pressure of the water.

The theory of the author of the paper is that the water that produced the scour escaped from an adjoining bell-joint. The action of the leakage water, under the circumstances, would make two short, nearly right angle turns, and after finally escaping, would be projected in a nearly horizontal direction parallel to the pipe, and thus encountering a rounded surface of iron on one side and the natural earths on the other, as mentioned by the author, its force would be so diffused that it could only act upon the weaker material—the sand, and would have no force left to act upon the iron.

If the iron pipe contained scoria also, as the surface showed, it would have but little coherence or strength, and its surface might be rapidly worn away, and produce the result which the specimen exhibits. This specimen evidently had not sufficient strength to resist the pressure of water from the interior of the pipe to which it is said to have been subjected.

I differ entirely from the author's theory that the hole in this pipe was or could have been produced by or on the principle of a "sand blast," so called.

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* December 19th, 1878. The piece of pipe containing the hole as described in the above paper, was exhibited.

ERRATA.

In paper (CLII, Vol. VI), entitled "Notes and Experiments on the use and testing of Portland Cement," by William W. Maclay, C.E., in Table 20, Page 363, the last five columns of Analyses, Nos. 7, 8, 9, 10, and 11, and the Remarks, should read, as follows:

7	8	9	10	11	
English Portland.	German Portland, Bonn, "Mining and Smelting Union."	German Portland, Kraft, and Saulich.	American Portland, "Saylor's from Coplay, Penn., U. S."	American Portland, "Saylor's from Coplay, Penn., U. S."	REMARKS.
Hopfgartner.	Hopfgartner.	Feichtinger.	F. A. Cairns. 1877.	F. A. Cairns. 1877.	
55.06	57.83	55.28	56.35	61.05	In Analysis Nos. 10 and 11, alkalies were undetermined. The figures opposite Sulphate of Lime, Ca. So_4 in these two Analyses, represent percentages of Sulphuric Acid, So_4.
22.92	23 81	22.86	21.12	21.18	
8.00	9.38	9.03	11.42	8.50	
5.46	5.22	6.14	1.73	2.50	
0.77	1.35	1.64	4.92	3.57	
1.13	0.59	0.77	......	......	
1.70	0.71	....	......	......	
1.75	1.11	3.20	1.73	2.19	
2.27	......	1.08	.. ...	......	
acid.			2.67	0.93	
			......	......	